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**FINAL REPORT TO THE AFOSR**  
**Research in Scanning Tip Microscopy**

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Tucson, Arizona 85721

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PREC QUALITY INSPECTION

Our work, prior to the current AFOSR support, resulted in the following publications where scanning tunneling microscopy and atomic force microscopy have been used to investigate (a) forces and (b) surfaces.

**a. Forces**

1. Dror Sarid, Douglas Iams, Volker Weissenberger, and L. Stephen Bell, "Compact Scanning Force Microscope Using a Diode Laser," Opt. Lett. **28**, 335 (1988).

**b. Surfaces**

2. Dror Sarid, Brian P. McGinnis, and Tammy D. Henson, "Four-wave mixing and scanning tunneling microscopy of semiconductor clusters," SPIE **881**, 114 (1988).
3. Dror Sarid, Tammy D. Henson, L. Stephen Bell, and Claude J. Sandroff, "Scanning tunneling microscopy of semiconductor clusters," J. Vac. Sci. Technol. A **6**, 424 (1988).
4. Dror Sarid, Tammy D. Henson, Neal Armstrong, and L. Stephen Bell, "Probing of Basal Planes of MoS<sub>2</sub> by Scanning Tunneling Microscopy," Appl. Phys. Lett. **52**, 2252 (1988).

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5. Tammy D. Henson, Dror Sarid, and L. Stephen Bell, "Scanning Tunneling Microscopy of Layered-Structure Semiconductors," *J. Microscopy* **152**, 467 (1988).
6. Dror Sarid, "Holographic display of scanning tunneling microscopy images," *Optics News*, August, 11 (1988).

During the current granting period, we have expanded our work and published papers in (a) forces, (b) surfaces, and (c) biology. The titles of the papers explain in some detail the directions we chose to take in the broad range of areas associated with scanning tunneling microscopy and atomic force microscopy. The work reported here includes investigations done in air, liquids, and under ultra-high vacuum conditions, using Digital Instruments' Nanoscope-II (three systems), Nanoscope-III, and McAllister UHV STM head. The many names appearing in the publications attest to the strong collaboration with other groups. The support of the AFOSR has been a key factor in making our research possible, and we plan to continue this effort during the second granting period.

#### **a. Surfaces**

1. T. Iwabuchi, C. Chuang, G. Khitrova, M. E. Warren, A. Chavez-Pirson, H. M. Gibbs, D. Sarid, and M. Gallagher, "Fabrication of GaAs nanometer structures by dry etching," *SPIE* **1284**, 142 (1990).
2. T. Chen, S. Howells, M. Gallagher, L. Yi, D. Sarid, D. L. Lichtenberger, K. W. Nebesney, and C. D. Ray, "Modelling of Internal Structure of Monolayer  $C_{60}$  Molecules on a Gold Substrate," *Proceedings of the 1991 Materials Research Society Symposium*, Vol. 208, p. 721.

3. T. Chen, S. Howells, M. Gallagher, L. Yi, D. Sarid, D. Lichtenberger, and C. Ray, "Internal Structure and Two-Dimensional Order of Monolayer  $C_{60}$  Molecules Observed with STM," *J. Vac. Sci. Technol.* **B9**, 2461 (1991).
4. D. Sarid, T. Chen, S. Howells, M. Gallagher, L. Yi, D. Lichtenberger, and D. Huffman, "Atomic Force Microscopy and Scanning Tunneling Microscopy of Monolayer  $C_{60}$  Molecules on a Gold Substrate," *Ultramicroscopy* (in press, 1992).
5. S. Howells, T. Chen, M. Gallagher, D. Sarid, D. L. Lichtenberger, L. L. Wright, C. D. Ray, D. R. Huffman, and L. D. Lamb, "High Resolution Images of Single  $C_{60}$  Molecules on Gold (111) using Scanning Tunneling Microscopy," *Surface Science* (in press, 1992).
6. L. D. Lamb, D. R. Huffman, R. K. Workman, S. Howells, T. Chen, D. Sarid, and R. F. Ziolo, "Extraction and STM Imaging of Spherical Giant Fullerenes," *Science*, March 13 (1992) p. 1413.
7. T. Chen, Sam Howells, M. Gallagher, D. Sarid, L. D. Lamb, R. Huffman, and R. K. Workman, "Scanning Tunneling Microscopy and Spectroscopy Studies of  $C_{70}$  Thin Films on Gold Substrate," *Phys. Rev. B Rapid Commun.* (in press, 1992).
8. S. Howells, M. Gallagher, T. Chen, and D. Sarid, "Oxidation Effects on Cleaved Multiple Quantum Well Surfaces in Air Observed by Scanning Probe Microscopy," *Appl. Phys. Lett.* (submitted, 1992).
9. M. J. Gallagher, S. Howells, L. Yi, T. Chen, and D. Sarid, "Photon Emission from Gold Surfaces in Air Using Scanning Tunneling Microscopy," (submitted, 1992).

#### **b. Forces**

10. Dror Sarid, Volker Weissenberger, Douglas A. Iams, and Jeffery T. Ingle, "Theory of the laser diode interaction in a scanning force microscope," *IEEE J. Quant. Electron.* **25**, 1968 (1989).
11. Dror Sarid, Douglas Iams, Jeffery Ingle, Volker Weissenberger, and Josef Ploetz, "Performance of a Scanning Force Microscope Using a Laser Diode," *J. Vac. Sci. Technol.* **8**, 378 (1989).
12. S. Howells, M. Gallagher, L. Yi, T. Chen, and D. Sarid, "Enhanced Effects with Scanning Force Microscopy," *J. Appl. Phys.* **69**, 7330 (1991).
13. L. Yi, D. Sarid, S. Howells, M. Gallagher, and T. Chen, "Combined STM-AFM for Magnetic Applications," *Proceedings of the 1992 American Institute of Physics Conference on Scanned Probe Microscopy*, vol. 241, p. 537.
14. Dror Sarid and Virgil Elings, "Review of Scanning Force Microscopy," *J. Vac. Sci. Technol. B* **9** (2), 431 (1991).
15. Dror Sarid, *Scanning Force Microscopy* (Oxford University Press, 1991).
16. Dror Sarid, Paul Pax, Leon Yi, Sam Howells, Mark Gallagher, Ting Chen, Virgil Elings, and Dan Bocek, "Improved Atomic Force Microscope using a Laser Diode Interferometer," *Rev. Sci. Instrum.* (in press, 1992).

#### **c. Biology**

17. Dror Sarid, Edmond H. Thall, Douglas A. Iams, Jeffery T. Ingle, Tammy D. Henson, Y. C. Lee, and L. Stephen Bell, "Scanning Tip Microscopy with Applications to Biology," *SPIE* **42**, 1063 (1989).

18. S. R. Hameroff, Y. Simic-Kristic, L. A. Verneti, Y. C. Lee, Dror Sarid, J. Weidmann, V. Elings, K. Koller, and R. S. McCuskey, "STM of cytoskeletal proteins: microtubules and intermediate filaments," *J. Vac. Sci. Technol.* **8**, 687 (1990).
19. L. A. Verneti, C. L. A. Nowline, S. R. Hameroff, A. J. Gandolfi, Y. C. Lee, and D. Sarid, "STM resolution of surface features on cytokeratin protein is enhanced by prolonged exposure of protein to cold temperatures," *J. Vac. Sci. Technol. B* **9**, 1223 (1991).
20. L. A. Verneti, D. Sarid, A. J. Gandolfi, A. E. Cress, R. B. Nagle, R. McCuskey, and S. R. Hameroff, "STM images of cytokeratin and binding IgG antibody," *Proceedings of the 1992 American Institute of Physics Conference on Scanned Probe Microscopy*, vol. 241, p. 232.
21. L. A. Verneti, Dror Sarid, A. J. Gandolfi, A. E. Cress, R. B. Nagel, R. McCuskey, and S. R. Hameroff, "The topographical structure of cytokeratin intermediate filaments using scanning tunneling microscopy," *Nanobiology* (in press, 1992).